International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 2, Apr 2020, 237–246

MECHANICAL BEHAVIOR OF GRAPHITE/GRANITE PARTICLES REINFORCED Al-Si ALLOY BASED COMPOSITES BY STIR CASTING ROUTE

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ABSTRACT

Al-Si alloy reinforced with the particulates of granite acquired from cutting of rock stones along with the graphite particles have good mechanical properties. The composite materials were prepared with various weight proportions of the strengthening particles to evaluate the mechanical characteristics. This has been achieved by manufacturing by stir casting method, hardness, density studies of tensile and compression on both alloys and composites were completed. Better durability and tensile properties for each composite were observed. Conveyance of rock and graphite particles in aluminum alloy matrix improves hardness of lattice material.

KEYWORDS: Al-Si alloy, Granite Particles, Graphite, X-Ray Diffraction and Energy Dispersive Spectroscopy.

Received: Jan 15, 2020; **Accepted:** Feb 05, 2020; **Published:** Feb 29, 2020; **Paper Id.:** IJMPERDAPR202021

Original Article

NOMENCLATURE:-

ρ_{MMC} = composite density

m= composite mass

m_1= composite mass in distilled water

ρ_{H2O}= distilled water density

V_r = reinforcement weight ratio

ρ_r = reinforcement density

ρ_c = density of composite

ρ_m =density of the unreinforced alloy

1. INTRODUCTION

With the advent of specified reinforcements the aluminum matrix composites are becoming ravishing materials for advanced aerospace and despite their properties car structures can be customized [1, 2]. At the elevated temperatures, many materials fails to perform the modulus property and by substituting these with the composite materials the mechanical properties can be enhanced. To enhance the MMC's properties of normally reinforced particles of order in microns are used. Flyash is the lowest density and conservative fortification reachable in mass amounts which is obtained as a byproduct in power plants. Hassan S.F et al. [3] examined the scanning electron micrographs of SiC as strengthening particle in metal matrix composites manufactured by secondary processing and

recognized higher strain to fracture values for the deformed material and further more sinter forged test castigated the higher value of flexible modulus and ultimate rigidity because of the molecule fracture because of crack. Kwok et al [4] reported that coalesce of hard particles in Al-Si alloy deteriorates the crystal bonding and results in evacuating of the SiC particles. The cross-section stressing in the neighboring regions of the particles will lessen the degree of plastic disfigurement that these zones can experience, which will make them increasingly sensitive against breaking. These splits will allow the lattice to be removed from the combining regions of the particles, subsequently diminishing the quality of the interfacial bond. Attempts have been made in the present work to obtain excellent properties of high specific strength with good wear-resistant properties.

2. EXPERIMENTAL WORK

2.1. Refinement of Granite Powder

Table 1: Chemical Composition of Granite Powder

Constituents	Weight Percentage
Al_2O_3	14.4
CaO	1.82
MgO	0.71
SiO_2	72.4
K_2O	4.12
Na_2O	3.69
Fe_2O_3	1.22

The granite particle was taken as strengthening material and obtained from local stone crushing units. The as received granite particles chemical composition of the powder was given in table 1. 500 grams of granite powder was taken in a graphite crucible and preheated for 4 hours at 850^{o}C in the muffle furnace to determine the ignition loss. Preheated granite particles were washed with distilled water after cooling to room temperature and then heated at 120^{o}C for a duration of 48 hours to make it dry. Initially, granite powder is greyish in color and after processing it turns to brikish as shown in Figure 1. The processed granite powder is sieved with meshes of 100 to 350 of sieve shaker for 15 minutes and results show that over 70 percent by weight remained in-200 + 350 mesh with an average particle size of 53 µm, this size was chosen as a strengthening for the development of hybrid composite.

(a) (b)

Figure 1: (a) Granite powder Initial Condition (b)Granite Powder After Refinement.

2.2.X-Ray Diffraction Pattern

X-ray diffractometer is used to classify the mineralogical components in a Sheifert Model URD 65, which operates with Cu-Kα radiation for a 2θ variation from 5º to 65º. The x-ray diffraction pattern of granite 50-53 µm is as shown in the figure 2 shows the compounds consisting of mineral amphibolic (hornblende), feldspar (microcline, albite, and anorthite) and quartz. The peaks depicted with MI (miller indices) represent the characteristic granite peaks (ICDD CARD No: C000560159). Different peaks may be a result of another period of any antecedent materials or pollutions or may be a direct result of any type of middle stage. The normal molecule size determined by Scherrer's formula is 9.0006 A^{O}figure 2 shows XRD of granite powder.

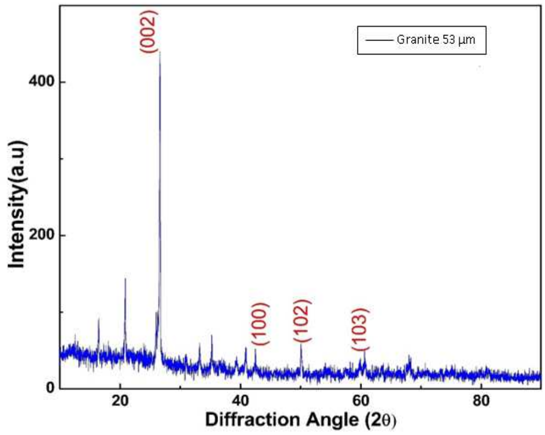

Figure 2: X-Ray Diffraction Pattern of Granite Powder.

2.3.Fabrication of Metal Matrix Composites

In this study, aluminum-based hybrid composites containing various mixtures of granite and graphite particles addition of 53µm reinforcements were effectively manufactured by vortex method. Table 2 shows the composition of aluminium-silicon alloy.

Table 2: Chemical Composition of Al-Si Alloy, wt. %.

Si	Mg	Cu	Fe	Ti	Al
6.5	0.4	0.05	0.09	0.06	Balance

Al-Si alloy is melted in electric furnace by using graphite crucible. The arrangement for the stir cast is depicted in figure 3, when the temperature reaches 770^{0}C a pool was created. The preheated granite and graphite particulates were first mixed into the Al-Si melt in different weight percentages of 2% graphite and 2% granite in first case and by keeping the graphite reinforcement as constant the granite weight percentage is increased to 4%. To ensure uniform distribution of strengthening particles in the pool, a cone shaped object is utilized .To prevent the oxidation inert gas preferably argon is impinged around the melt and fingers were casted in a permanent die as shown in figure4.

Figure 3: Experimental Setup of Stir Casting.

Figure 4: Fabrication of Fingers.

2.4. Hardness Analysis

Vickers micro hardness tester (Model: VHS 5B-Banbros) is used to find the hardness of the composites and base alloy by taking 10 readings on an average.

2.5. Density Analysis

By using the technique of Archimedes drainage method the densities of composites and base alloy were found by using the relation:

$$\rho_{MMC} = \frac{m}{(m-m_1)\times(\rho_{H_2O})}$$

And by using the concept of rule of mixtures the analytical density calculations was done using following relation.

$$\rho_c = V_r \rho_r + (1-V_r)\rho_m$$

3. RESULTS AND DISCUSSIONS

3.1. Microstructural Study

To evaluate the morphological changes and elemental analysis of the composites and base alloy, a Scanning electron microscopy was used. Figure 5 (a),(b),(c),(d) illustrates the Al-Si alloy SEM micrograph in which needle particles indicates Si, graphite and granite particles are identified and displayed in magnified view.

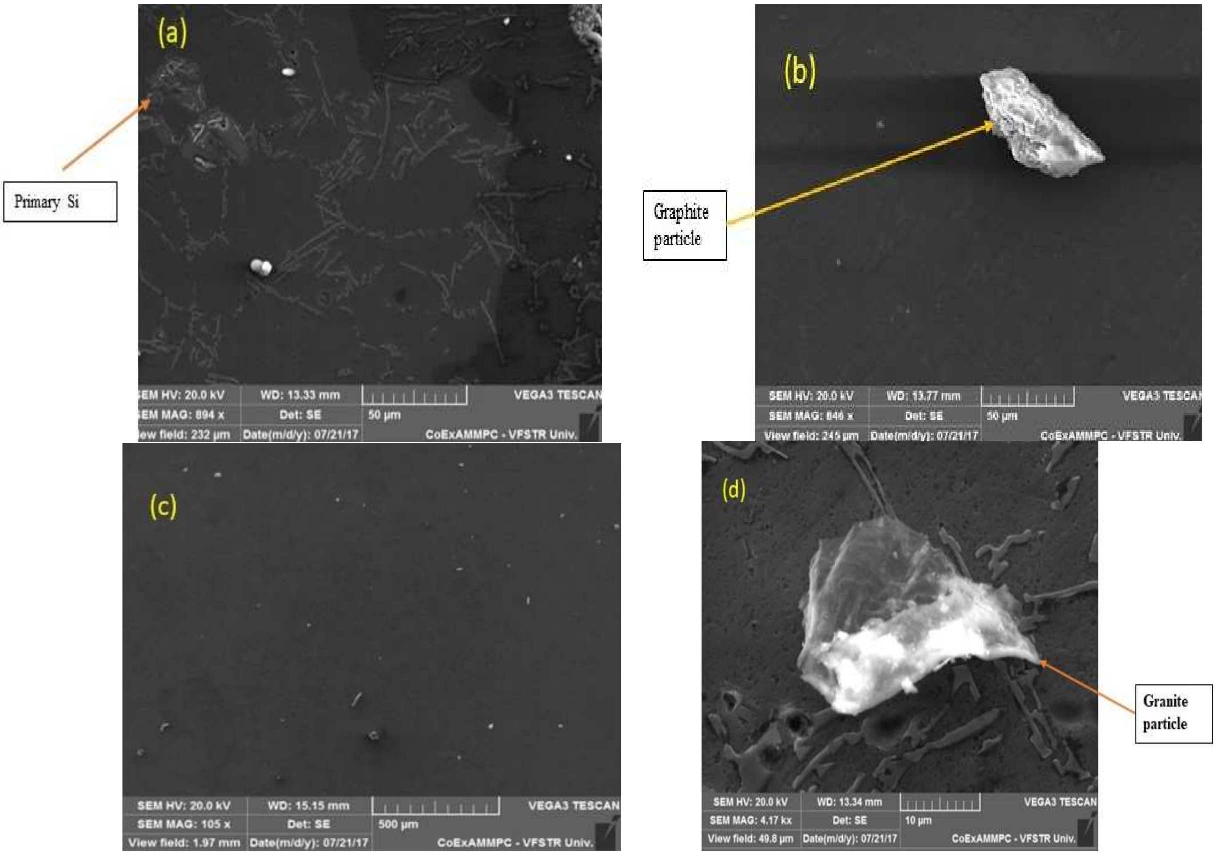

Figure 5: (a) SEM Micrograph Al-Si Alloy (b) SEM Micrograph of Graphite Particles (c) Particle Distribution in Low Resolution (d)SEM Micrograph of Granite Particles.

3.2.Energy Dispersive Spectroscopy Analysis

Figure 6 (a), (b) shows the existence of Silicon, Aluminium,and Magnesium in the matrix phase obtained from the EDS composite spectrum, silicon and other components in composite-reinforced graphite granite as shown in figure 7 (a), (b). Also no contamination had taken place because of argon gas shielding continuously and no oxygen traces were found in the matrix.

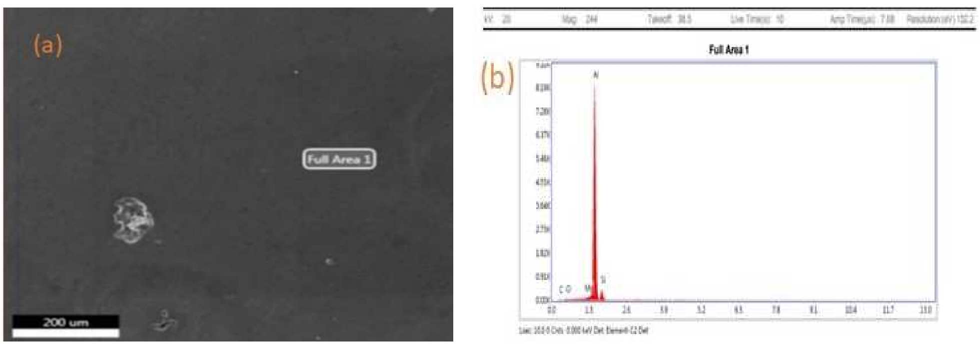

Figure 6: (a), (b) Energy Dispersive Spectrum of Al-Si Alloy.

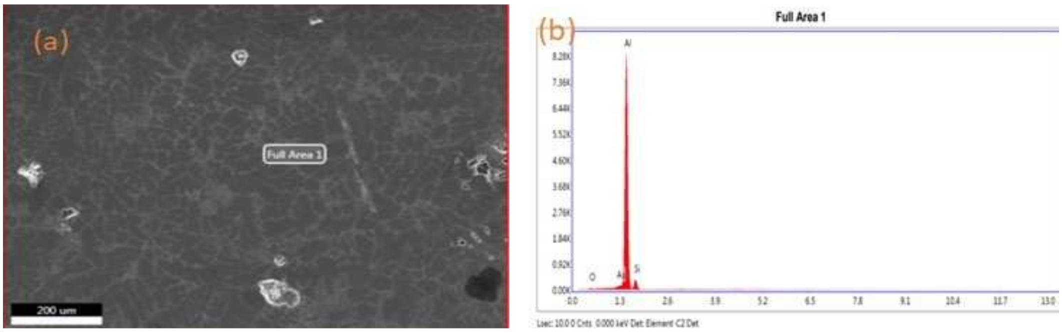

Figure 7: (a), (b) Energy Dispersive Spectrum of Graphite and Granite Composite.

3.3. Density and Hardness Studies

Table 3 shows the standard analytical and experimental density values for the base alloy and the subsequent composites. It was observed that the addition to the Al-Si alloy matrix of 2 percent graphite and 4 percent granite particles significantly decreases the density of the resulting composites compared to the base alloy.

Table 3: Analytical and Measured Densities of Al-Si Alloy and Composites

S. No	Sample	Density (g/cm^3)	
		Analytical	Measured
1.	Al-Si alloy	2.8	2.8
2.	2% graphite composite 1	2.79	2.76
3.	2% graphite + 4% granite composite 2	2.76	2.73

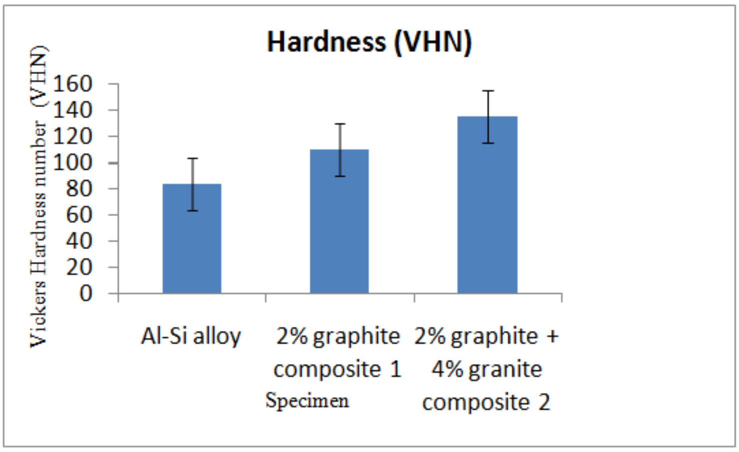

Figure 8: Hardness Values of Composite Samples.

With the increase in the percentage of graphite and granite particulates the densities of the composites decreases as shown in table 3. The observed densities are therefore lower than the values derived from theoretical calculations. A material's hardness is a physical criterion which indicates the ability to withstand local plastic deformation. The Figure 8 indicates that composite 1 and composite 2 hardness increased to 110 and 135 VHN from 84 VHN in Al-Si alloy. This could be attributed to the Si and Al_2O_3 and silica predominant pieces that are strong in nature. M.G. Krishna et.al.[5, 6] reported similar findings.

3.4.Tensile Studies

Using INSTRON tensile testing machine, elastic properties of manufactured composites were determined according to ASTM, E-8 standards as shown in figure 9 (a) and plotting has done repeatedly. Table 4 shows the tensile behavior of the composite and figure 10(a), (b) shows the specimens before and after fracture. The composite with 2% graphite and 2% granite (C2) shows an increased ultimate and yield strength relative to the base matrix and an improvement is also seen in the modulus of elasticity.

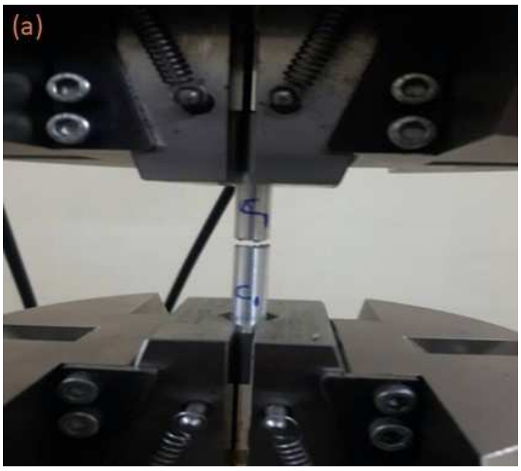

Figure 9: Tensile Test on Sample.

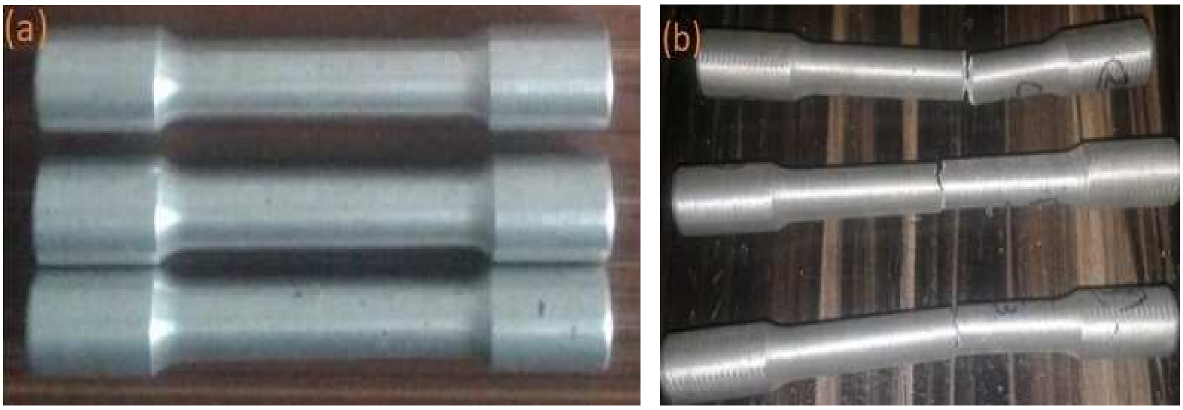

Figure 10: (a) Composite Specimens Before Tensile Test (b) Tensile Specimens After Fracture.

From Table 4, it is found that the tensile strength of the composites is greater than their base matrix. Maleq et al. [7] reported that the responsible mechanism for the marvels incorporates load transfer from the alloy phase to the particle which has high strength and stiffness.

Table 4: Tensile Strength of Al-Si Metal Matrix Composites

Alloy and Composites	Yield Strength (MPa)	Ultimate Tensile Strength (UTS) (MPa)	Young's Modulus, GPa
Al-Si alloy	65.09	102.30	9.7
C1 (2% Graphite)	86.31	128.07	16.2
C2 (2% Gaphite+2%Granite)	88.44	170.71	16.6
C3 (2% Gaphite+4%Granite)	86.87	148.17	15

The fracture behavior and tensile deformation of the 6061 alloys reinforced with silicon carbide was studied by Lloyd [8] stated that the elastic modules of intermittently strengthened composites were supposed to work as a fraction of the reinforcement volume. Lorca and Gonzalez[10] stated that, with the rise in the volume fraction of the reinforcement, the UTS, yield strength and the Elastic composite modulus improved, while the ductility decreased. Because of the constraints imposed on the deformation induced by the presence of hard and brittle Al2O3particles in the soft and ductile 6061 Al alloy matrix higher applied stress is needed to set off plastic deformation in the matrix. Figure 11(a) indicates a crack for alloy Al-Si alloy and figure 11(b, c) shows that the typical character of a fracture with no apparent dimple and tear ridge structures is observed for 2 per cent graphite and granite hybrid fractured specimens. It can be seen that the addition of graphite and granite particles into matrix alloy increases the elastic strength. This was due to the hard granite particle shape at the edge used in this study. And they also stated that the increase in the load borne by the particulates during the plastic shear at the starting phase was due partly to the strain hardening of the neighbouring matrix, which is relatively ductile in nature. Several authors[11-12] reported inundated stress relaxation from broken particles allowing stress transfer to surrounding particles resulting in increased particle fracture. They also concluded that the final fracturing of the composites happens through a ductile process involving the nucleation and development of the matrix voids, which leads to the final coalescence of the larger voids that exist around the broken particles.

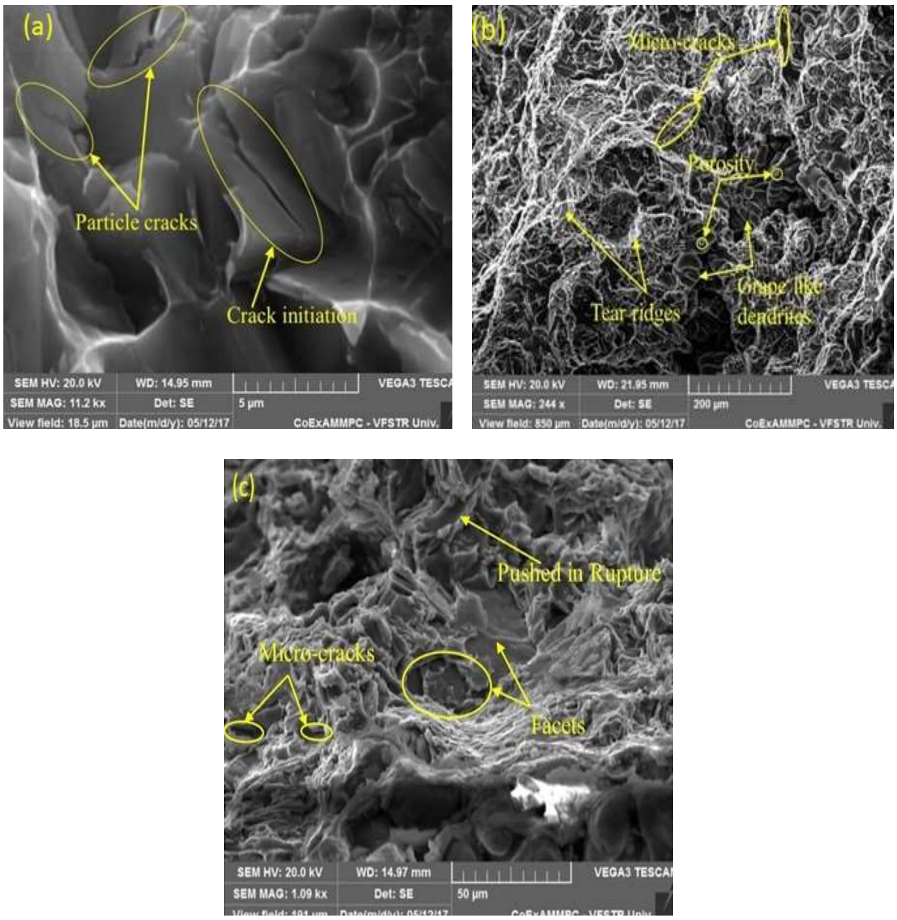

Figure 11: (a) SEM Micrograph of Al- Si Alloy
(b),(c) SEM Micrographs of Fractured Graphite, Granite Composite

4. CONCLUSIONS

Al-Si alloy combined with hybrid graphite and granite particulate composites was produced successfully using vortex. The strengthening particles were evenly distributed in the matrix phase. The SEM results show a strong interfacial bonding, which clearly shows that the composites did not contain discontinuities and voids.

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